The Relationship of Environmental Lead to Blood-Lead Levels in Children[1]

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An in-depth study of the distribution of lead sources in the residential environment of 377 children in New Haven, Connecticut, was carried out. Substantial amounts of lead were present in soil, paint, and house dust throughout New Haven, but not in air or water. Multiple regression modeling indicated that the most important contributors to variation in children's blood-lead levels were soil lead and exterior house paint lead. Using the best five-variable model only 11.7% of the variation in the children's blood-lead levels could be explained. This led to the conclusion that availability of lead in the residential environment did not account for most of the variation observed in the population.

INTRODUCTION

Abnormal ingestion of leaded paint has been consistently implicated as the primary cause of lead poisoning with clinical symptoms in urban children (Barltrop, 1973). The amount of lead present, as well as its accessibility, depends upon the age of the residence and the physical condition of the paint. Lead pigments were the first pigments produced on a large commercial scale when the paint industry began its growth in the early 1900s. Childhood lead poisoning was attributed to ingestion of these pigments in house paint in Queensland, Australia,

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soon after that time. By the 1920s laws had been passed to prohibit the use of lead-based paint in that part of Australia in applications where children could reach it (Henderson, 1963). The Australian experience attracted little attention elsewhere for many years. Nevertheless, principally for reasons of cost, lead pigments were gradually replaced with zinc and other opacifiers beginning in the 1930s. By the 1940s titanium dioxide became available and has now become the most commonly used pigment for residential coatings. There was no regulation of the use of lead in house paint in the United States until the mid-1950s.

In 1955, the paint industry adopted a voluntary standard that limited the lead content in paint for interior uses to no more than 1% by weight of the nonvolatile solids. At about the same time, local jurisdictions began adopting codes and regulations that prohibited the sale and use of interior paints containing more than 1% lead (Berger, 1973). These regulations often also required lead hazard abatement when the paint was loose, flaking, peeling, or broken; or in some cases, when it was on surfaces within reach of a child's mouth.

The level of lead in paint in a residence that should be considered a hazard remains in doubt. Generally, the lowest lead level considered to be hazardous ranges from 0.5 to 2.5 mg of lead/cm^2 of painted surface. This standard is concerned with the amount of lead that might be available from peeling paint, broken plaster, or damaged surfaces to which children may have access. It does not correlate directly or consistently with the percentages of lead allowed in paints today, because it includes lead that may be present in several layers of paint on a surface. The selection of this lead level appears to be dependent more on the sensitivity of field measurement devices (X-ray fluorescent lead detectors) than on a direct biological dose–response relationship (Air Quality Criteria for Lead, 1977).

Although most authors have stated that the source of exposure in childhood lead poisoning is primarily peeling lead paint, broken lead-impregnated plaster, or paint chewed from window sills, and sometimes outdoor porches, in poorly maintained houses, there are also reports of cases where exposure cannot be equated with the presence of lead paint. The analysis of paint in homes of children with lead poisoning has not consistently revealed a hazardous lead content (Lin-Fu, 1973). Data from the Center for Disease Control also show that a significant number of children with undue lead absorption occupy buildings that were inspected for lead-based paint hazards, but in which no hazard could be demonstrated. These data show that in about 40 to 45% of confirmed cases of elevated blood-lead levels, a possible source of lead paint hazard could not be located (Hopkins and Houk, 1976; Morbidity and Mortality Weekly Report, 1977). These findings do not necessarily exclude lead-based paint as a major environmental source of lead for children, but they do support the concept that lead paint is not the only source of exposure that contributes to the total body burden.

There is evidence that ingestion of contaminated street dirt and house dust is involved in the development and maintenance of increased blood-lead levels, especially "borderline elevations" (Darrow and Schroeder, 1973). Yankel *et al.* (1977) showed that lead in both soil and dust was independently related to blood-lead levels. In their opinion, 1000 ppm soil lead exposure was cause for concern.

Lead levels of this magnitude and greater have been found both in central city (Lepow *et al.*, 1975) and surburban communities (Kreuger, 1972a,b).

Several studies have looked at the relationship between lead in air and lead in blood of children (Yankel *et al.* 1977; Solomon and Hartford, 1976; Lepow *et al.*, 1974). These studies indicated that even though air was the principal source of lead, inhaled lead per se was not as significant as the ingestion of contaminated soil and dust. It was shown (Yankel *et al.*, 1977) that the lowest air-lead concentration which was associated with significant elevation of blood-lead levels was 1.7 $\mu g/m^3$.

It is evident that multiple sources of exposure to lead exist in the environment and that children's blood-lead levels reflect absorption from each of these sources.

New Haven

Housing. New Haven, Connecticut, has the same problems of housing and concentration of deprived populations as do most older eastern seaboard cities. Although New Haven participated in the Model Cities Program, which involved extensive rehabilitation[3] of depressed neighborhoods, there remain several thousand dwelling structures of frame construction built before 1940. Lead-based paint was commonly used on the interior surfaces of these housing units until the 1950s and is still being used on exterior surfaces. On the basis of information contained in the "Annual Housing Survey: 1974, Part B" (Annual Housing Survey, 1974), some estimates of housing ownership and quality were made. Approximately 38% of dwelling units are owner-occupied as opposed to rented. Owner occupants generally live longer at an address, tend to rate their homes, streets, and neighborhoods higher and express less of an interest in moving than do renter occupants.

Childhood lead poisoning. The New Haven Health Department has been actively concerned with detection and prevention of childhood lead poisoning since 1961, when two children died of the disease. Since that time lead intoxication has been the reported cause of an additional six deaths in the city.

Over the past ten years the Health Department and other health care providers became increasingly aware of the complex environmental–medical–social problems underlying the recurrent cases of childhood lead poisoning. It was evident that an expanded effort toward identification and treatment of children with elevated blood-lead and reduction of their exposure to environmental lead was needed.

From September 1974 to February 1977, an extensive federally supported screening and control program[4] for childhood lead poisoning was carried out by the Health Department. This program has been described elsewhere (Stark *et al.*, 1978).

Environmental exposure to lead. In order to obtain a perspective on the distribution of environmental lead sources accessible to children and on the relation-

[3] According to the 1970 census there were 48,893 dwelling units in New Haven. During the period 1956–76 approximately 5000 of the oldest, most dilapidated units were demolished. This indicates a rate of replacement of units of about 10% of available housing stock every 20 years.

[4] U.S. Department of Health, Education and Welfare, Public Health Service.

ship of these sources to blood-lead levels, an in-depth study on a subset of the screened children was carried out. This report describes the outcome of the study. Specifically, the following issues are addressed: (1) what are the important environmental sources of lead in New Haven; (2) how are these sources distributed throughout the city; and, (3) what is the relationship of these sources to the observed blood-lead levels of children exposed to them.

MATERIALS AND METHODS

Study Population and Variables of Interest

Because of the large-scale screening program, it was possible to obtain detailed information on a cross-sectional sample of the population of interest. This sample was composed of 8289 children in the age group 1 through 72 months and represented about 80% of the entire population of that age group. For each of these children the following minimal information was collected: child's age, blood-lead level, and address within New Haven city limits. Out of the 8289 children, a subset was selected for participation in the in-depth environmental lead exposure study. The criteria for inclusion in this subset were: (1) the child must have lived at the same address for at least 1 year; (2) the child must have had at least two blood tests during that time, both of which were ≤29 $\mu g\%$ or 30–39 $\mu g\%$ or ≥40 $\mu g\%$. Of the 784 children eligible for inclusion into the study group, on the basis of criteria (1) and (2), 407 children were excluded due to either of the following factors: (a) family moved prior to attempted inspection by the project sanitarian; (b) parent(s) refused to allow inspection by the project sanitarian. This left 377 children to make up the study group upon which this report is based. The homes of children in the study group were tested for the level of lead in house dust, in interior and exterior paint, and in soil both close to the structure and close to the street. In addition, estimates of housing condition, paint and plaster condition, and housekeeping quality were made. The method of housecleaning (vacuum cleaner or dust mop and rag) was ascertained as well. For each home, ownership and age of the structure was obtained. Socioeconomic status (SES) and air-lead level were derived for each child from his census tract of residence.[5]

Methods of Measurement

The blood-lead measurement is generally accepted as the best indicator of the external dose of lead (Chisolm et al., 1975) where the external dose is the concentration of lead within a given volume of material ingested or inhaled. In this study, micro (0.25 ml) samples of blood were collected by a standardized technique and sent to the State Health Department Laboratory Division in Hartford, Connecticut, for analysis. Analysis was performed using atomic absorption spectrophotometry with a Delves' cup attachment. Blood-lead measurements were used as the indicator of lead absorption in the New Haven study population; therefore, the accuracy of the screening results were assessed. The data are be-

[5] Water lead was not considered because all water in New Haven is supplied by a single source (lead content < 0.01 ppm) which meets the Public Health Service standard of 50 μg/liter. A sample of 2% of water supplies was analyzed for lead during the course of routine investigation of households where a child with an elevated body burden of lead resided; all were negative.

lieved to be accurate (Quah *et al.*, 1980) and any discernible patterns reflective of true patterns occurring in the population.

The project sanitarian obtained a dust swipe on a preweighed cotton gauze from under the bed or over a door jamb in each house. Lead levels in soil were derived from samples of 5–10 g of soil taken near the structure and from similar samples taken near the street. Samples were from the top half inch of soil and were collected using lead-free tools and stored in plastic bags. The soil and dust samples were analyzed by Environmental Sciences, Associated, Inc., using atomic absorption spectrophotometry. Quality control in the laboratory consisted of occasional split sampling. Similar results were obtained for split samples. All samples were collected by a single sanitarian, thereby assuring consistency in the collection method.

Interior and exterior paint lead levels were obtained using a portable X-ray fluorescence lead detector (Spurgeon, 1973). For interior levels, the sanitarian took three readings from the kitchen walls and recorded the highest value. Similarly, a value for the child's bedroom was recorded. For exterior paint levels, the highest of three readings was recorded for lead on exterior porch or stairs and on a side of the house. The lead detector was calibrated periodically in order to ensure accurate readings. The sanitarian was the only person who took readings, so that there was no problem of interobserver variability.

When the sanitarian visited each house to obtain environmental samples, he questioned the family as to how they cleaned their house. He also made assessments of the quality of housekeeping, the overall physical condition of the structure, and the level of chipping, peeling, and flaking of paint and plaster. Again, internal consistency was maintained because the same individual assigned the values for these variables.

Housing ownership was obtained from the records of several sources, including the New Haven Housing Authority, the New Haven Housing Conservation and Code Enforcement Agency, the New Haven Health Department, and the City Directory, or from direct questioning of the occupant. The ages of dwelling structures came from the records of the New Haven Building Department.

Socioeconomic status was derived for each child from his census tract of residence using a factor analysis which ranks the 28 New Haven census tracts. The ranked census tracts were then grouped into five levels of socioeconomic status, with one being the highest and five the lowest.

Air-lead levels were estimated based on the mean values of 2 years of air sampling conducted by the Connecticut State Department of Environmental Protection. Sampling was done at four sites in the city and levels between sites were obtained by interpolation.

Methods of Analysis

Lead levels in blood and many environmental sources, including paint, dust, and soil, are distributed lognormally (Shubert *et al.*, 1967; Aitchison and Brown, 1966; Johnson and Katz, 1970); therefore, the median or geometric mean (GM) is the best estimate of central tendency. Analysis of these variables used geometric means and geometric standard deviations (GSD). For most analyses, the depen-

TABLE 1

DUST LEAD, PAINT LEAD, AND SOIL LEAD BY SOCIOECONOMIC STATUS OF RESIDENCE AREA.
NEW HAVEN, CONNECTICUT, SEPTEMBER 1974–FEBRUARY 1977

	Level of socioeconomic status				
	1	2	3	4	5
No. of children	16	25	92	109	135
Dust lead level (ppm)	159.3	489.2	603.9	628.6	391.6
	31.6	316.2	100.0	158.5	158.5
Kitchen paint lead level (mg/cm^2)	0.94	4.93	2.44	3.82	2.61
	2.34	2.20	2.53	2.37	2.85
Bedroom paint lead level (mg/cm^2)	1.59	4.39	1.79	2.07	3.05
	1.41	2.52	3.22	3.25	2.86
Porch paint lead level (mg/cm^2)	0.30	1.05	1.31	1.86	0.58
	2.70	2.29	3.33	2.96	3.75
Exterior paint lead level (mg/cm^2)	0.39	5.26	1.52	2.71	2.02
	2.77	2.73	3.71	3.17	3.35
Near soil lead level (ppm)	233.3	756.5	1327.3	830.5	703.5
	398.1	125.9	251.2	316.2	199.5
Far soil lead level (ppm)	209.5	700.1	660.1	665.2	599.0
	79.4	39.8	63.1	63.1	199.5

Note. First row under each category refers to the geometric mean and second row refers to the standard deviation.

dent variable was taken to be the log of the blood test result. Each variable in the data set was examined separately to determine its relationship with the dependent variable. Correlations between all continuous variables were determined. Regression on the log of the blood test result was done for each of the environmental lead variables. Finally, multiple regression techniques were carried out in an attempt to construct an appropriate model to explain the variations in blood-lead levels.

RESULTS

Table 1 summarizes environmental lead levels within each level of socioeconomic status. The environmental lead levels did not follow a direct trend in relation to socioeconomic status. In fact, socioeconomic status 2 had relatively high levels of lead present, whereas the lead levels in socioeconomic status 5 were often below those found in other areas.

Table 2 summarizes environmental lead levels with respect to the year of construction of the housing unit. Table 2 shows the newer houses had significantly less lead content both inside and outside than older houses. However, houses built during 1950–1959 showed high lead levels for all house lead measures except for porch lead.

Table 3 shows the bivariate correlations between the environmental lead sources. There are many significant correlations among the continuous variables

TABLE 2
Dust, Soil, and Paint Lead Levels by Year of Housing Construction,[a] New Haven, Connecticut, September 1974–February 1977

	1910–19	1920–29	1930–39	1940–49	1950–59	1960–69	1970–77
No. of children	41	42	29	86	29	30	3
Dust							
lead level	756.2	653.2	516.6	356.4	456.4	239.2	463.1
(ppm)	501.2	100.0	63.1	251.2	398.1	1995.3	20.0
Near soil							
lead level	1200.1	1273.3	1299.0	444.0	929.6	309.7	131.3
(ppm)	63.1	79.4	251.2	1258.9	398.1	501.2	50.1
Far soil							
lead level	798.2	770.1	917.6	507.4	479.3	390.2	310.9
(ppm)	39.8	39.8	39.8	316.2	100.0	50.1	63.1
Porch paint							
lead level	3.7	2.6	0.76	0.50	0.22	0.41	1.2
(mg/cm^2)	2.6	2.4	2.7	3.9	2.6	4.1	1.3
Exterior paint							
lead level	4.6	2.7	1.7	0.29	2.7	1.1	0.96
(mg/cm^2)	2.8	3.0	2.7	4.6	3.2	4.3	2.1
Kitchen paint							
lead level	4.0	4.3	4.3	1.2	4.3	1.6	1.9
(mg/cm^2)	2.5	2.3	2.4	3.1	2.6	2.7	1.8
Bedroom paint							
lead level	2.5	2.3	7.2	1.7	3.2	1.6	2.5
(mg/cm^2)	2.7	3.4	2.2	3.0	3.0	2.5	1.5

Note. First row under each category refers to the geometric mean and second row refers to the standard deviation.

[a] Year of housing construction was unavailable for 117 dwelling units.

given in Table 3. The year of housing construction is negatively correlated with lead levels in dust, kitchen paint, bedroom paint, porch paint, exterior paint, near soil, and far soil. Except for air lead all the environmental lead measures are highly correlated with each other.

Table 4 shows the proportion of variation in children's blood-lead levels which was associated with each of the environmental lead variables.

The significance levels in Table 4 indicate highly statistically significant relationships occurring. However, low r^2 values show that only a small percentage of blood-lead variation is "explained" by each of the environmental lead variables. It appears that the significant variables are each insufficient alone to account for much of the variation occurring in the blood-lead values. A multiple regression approach, incorporating several of these independent continuous variables as predictors, was suggested.

Tables 5 and 6 show the results of multiple regression modeling using environmental factors and socioeconomic status level. From Table 5 it can be seen that

TABLE 3

PEARSON PRODUCT MOMENT CORRELATIONS BETWEEN LEAD SOURCES IN THE RESIDENTIAL ENVIRONMENT, NEW HAVEN, CONNECTICUT, SEPTEMBER 1974–FEBRUARY 1977

	Air lead level	Dust lead level	Kitchen paint lead level	Bedroom paint lead level	Porch paint lead level	Exterior paint lead level	Near soil lead level	Far soil lead level
Year housing structure built	r = 0.1122 n = 276 P = 0.063	r = -0.2273 n = 277 P = 0.001	r = -0.2030 n = 278 P = 0.001	r = -0.0555 n = 278 P = 0.357	r = -0.3144 n = 276 P = 0.001	r = -0.2750 n = 276 P = 0.001	r = -0.2333 n = 275 P = 0.001	r = -0.2632 n = 277 P = 0.001
Air lead level		r = 0.0496 n = 373 P = 0.340	r = -0.0589 n = 374 P = 0.256	r = -0.0990 n = 373 P = 0.056	r = -0.0667 n = 372 P = 0.199	r = -0.0333 n = 372 P = 0.522	r = -0.0686 n = 371 P = 0.188	r = -0.1543 n = 373 P = 0.003
Dust lead level			r = 0.1923 n = 376 P = 0.001	r = 0.1574 n = 375 P = 0.002	r = 0.1457 n = 374 P = 0.005	r = 0.1982 n = 374 P = 0.001	r = 0.2515 n = 374 P = 0.001	r = 0.1539 n = 376 P = 0.003
Kitchen paint lead level				r = 0.3434 n = 376 P = 0.001	r = 0.0718 n = 375 P = 0.165	r = 0.1575 n = 375 P = 0.002	r = 0.2002 n = 374 P = 0.001	r = 0.1920 n = 376 P = 0.001
Bedroom paint lead level					r = 0.0253 n = 374 P = 0.650	r = 0.1425 n = 374 P = 0.006	r = 0.1068 n = 373 P = 0.039	r = 0.1449 n = 375 P = 0.005
Porch paint lead level						r = 0.2949 n = 375 P = 0.001	r = 0.2245 n = 372 P = 0.001	r = 0.1656 n = 374 P = 0.001
Exterior paint lead level							r = 0.4332 n = 372 P = 0.001	r = 0.2806 n = 374 P = 0.001
Near soil lead level								r = 0.3044 n = 374 P = 0.001

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TABLE 4

Proportion of Variation of Log of Blood-Lead Level Associated with Log of
Residential Environmental Lead Levels Available to Children,
New Haven, Connecticut, September 1974–February 1977

Environmental source	r	r^2	Significance Level	SE of slope Estimate	y Intercept	Slope
Log of dust lead	0.13488	0.01819	0.00469	0.14519	1.34418	0.04799
Log of kitchen lead	0.08136	0.00662	0.08768	0.14934	1.43589	0.02860
Log of bedroom lead	0.12265	0.01504	0.01778	0.14736	1.41164	0.03929
Log of porch lead	0.11695	0.01368	0.07041	0.15250	1.45042	0.03721
Log of exterior house lead	0.14273	0.02037	0.03457	0.14525	1.43178	0.03813
Log of near soil lead	0.22254	0.04952	0.00001	0.14247	1.30267	0.05963
Log of far soil lead	0.19767	0.03907	0.00006	0.14324	1.24529	0.08148

Note. r = Correlation coefficient. r^2 = Proportion of the total variation of the log of blood-lead level
that can be attributed to its linear regression on the log of each residential environmental lead level.

indoor paint lead levels do not explain the variation seen in blood-lead levels.
While overall condition is important, the condition of paint and plaster alone is
not. As was shown in Table 2, older housing had higher lead levels both inside and
outside. The protective nature of newer housing is illustrated in these models.

TABLE 5

Multiple Regression Models Using Independent Environmental Variables and
Socioeconomic Status to Account for Variation in the Log of Blood-Lead Level,
New Haven, Connecticut, September 1974–February 1977,
Best N Variable Models" (Based on 377 Children)

N	Variables	B_i	A	r^2
1	Log of porch lead level	0.05	1.43	0.04
2	Log of porch lead level	0.05	1.35	0.08
	Overall condition of house	0.06		
3	Log of porch lead level	0.06		
	Overall condition of house	0.06	1.27	0.09
	Socioeconomic status	0.02		
4	Log of porch lead level	0.05		
	Overall condition of house	0.05	1.33	0.10
	Socioeconomic status	0.02		
	Year of construction of house	−0.001		
5	Log of porch lead level	0.04		
	Log of exterior paint lead level	0.02		
	Overall condition of house	0.06	1.32	0.11
	Year of construction of house	−0.001		
	Socioeconomic status	0.02		

Note. B_i = Partial regression coefficients. A = Intercept. r^2 = Proportion of the total variation of the
log of blood-lead level that can be attributed to its linear regression on the independent variables in
each model.
" No significant increase in r^2 occurred beyond the inclusion of 5 variables. For 14 variables, r^2 = 0.117.

TABLE 6
LEVELS OF LEAD IN THE RESIDENTIAL ENVIRONMENT BY DWELLING UNIT OWNERSHIP.
NEW HAVEN, CONNECTICUT, SEPTEMBER 1974–FEBRUARY 1977

Environmental source	Owner occupied	Private rental	Public rental	Leased
Number of children	77	222.	75	3
Lead in porch paint	1.7	1.4	0.05	1.0
(mg/cm²)	3.0	3.2	6.3	0
Lead in exterior house paint	3.2	2.8	0.04	9.3
(mg/cm²)	3.0	3.1	7.2	0
Lead in near soil	1230.5	1003.2	153.2	1700.0
(ppm)	199.5	199.5	398.1	0
Lead in far soil	651.5	723.3	281.1	1500.0
(ppm)	50.1	63.1	125.8	0
Lead in kitchen paint	2.8	4.2	0.8	1.3
(mg/cm²)	2.5	2.4	1.7	0
Lead in child's bedroom	3.3	2.7	1.2	7.2
(mg/cm²)	2.6	3.1	2.7	0
Lead in house dust	609.4	541.0	250.0	980.0
(mg/cm²)	501.2	129.9	158.5	0

Note. First row under each category refers to the geometric mean and second row refers to the standard deviation.

Low level of socioeconomic status contributes to explaining increased blood-lead levels. It should be noted that a maximum of 11.7% of variation in blood-lead levels could be explained by environmental factors and socioeconomic status.

Analysis of residuals resulting from the multiple regression model presented in Table 5 was carried out. The model fits most of the data. However, a portion of the cases, while conforming well to the predicted dependent variable log of blood-lead level, have large residuals. These resulted from race–age differences. Therefore, attempts to create multiple regression models using subsets based on race, age, and race with age were made. These models proved less successful than

TABLE 7
CHILDREN'S GEOMETRIC MEAN BLOOD-LEAD LEVELS (µg/dl) BY THEIR AGE IN MONTHS AND
OWNERSHIP OF THEIR RESIDENCES, NEW HAVEN, CONNECTICUT, SEPTEMBER 1974–FEBRUARY 1977

Child's age (months)	Owner occupied	SD	Private rental	SD	Public rental	SD
12	23.8	1.43	25.8	1.37	24.8	1.35
24	28.9	1.42	28.3	1.44	27.9	1.32
36	26.1	1.44	28.8	1.42	28.9	1.29
48	23.4	1.43	28.6	1.38	25.8	1.29
60	25.5	1.40	27.4	1.40	27.0	1.28
72	22.3	1.32	26.6	1.37	26.6	1.30
All ages	24.8	1.35	27.7	1.35	27.0	1.29

the one presented here in terms of their ability to explain variation in blood-lead levels.

Table 6 gives the breakdown of each environmental lead source by dwelling unit ownership. The following observations may be made from Table 6, which relates housing ownership to environmental lead sources. Public rental housing has the lowest lead levels present among the four types of housing ownership. The three children living in leased housing all live in the same house. In New Haven, leased housing refers to units which the city leases from the owner, brings into compliance with the Housing Code, and then rents to individuals. This particular leased house had significant lead levels present, but cannot be taken to be representative of all leased houses. For five of the seven measures of housing-associated lead, owner occupied units were higher than both private or public rental units.

Table 7 shows the relationship of blood-lead levels by age to each type of housing ownership. When Table 7, which relates geometric mean blood-lead levels to housing ownership, is examined, it is clear that despite the greater amounts of lead present in owner-occupied housing, blood-lead levels are not significantly different from those of children living in public or private rental units.

DISCUSSION

An in-depth study on a subset of screened children was carried out in order to obtain an estimate of the distribution of environmental lead sources accessible to children and the relationship of these levels to children's blood-lead levels. It was found that substantial amounts of lead are present in soil, paint, and house dust throughout New Haven. The levels of lead in air and water met federal standards and were found to be far lower than those in soil, paint, and house dust.

There is a significant difference among socioeconomic status level groups in the mean level of each of the environmental lead measures. However, the relationship is not direct and, in fact, level 2 has high lead levels for all measures considered except porch lead level. Newer houses have significantly less lead content both inside and outside than older houses. Houses built during 1950–1959 have unexpectedly high lead levels for all house lead measures except for porch lead. Public rental housing has the lowest lead levels present among the four types of housing ownership. All public units were constructed after 1940. For five of the seven measures of housing-associated lead, owner-occupied units were higher than either private or public rental units.

When regressions of blood-lead level on the seven measures of environmental lead were done, the three most important variables were soil lead near the house, soil lead far from the house, and exterior paint lead. These are all measures of exterior sources of lead. Although owner-occupied units have the highest lead levels, children living in them had blood-lead levels from 4–16% lower, with an overall (all ages) lowering of 8%, than children living in private or public rental units.

The proportion of variation in blood-lead levels which could be explained by environmental variables and socioeconomic status using a multiple regression model was only 11.7%. This indicates that proximity of lead alone does not explain most of the variation which occurs in the population. Because the indicators

of socioeconomic status included in the model appeared important, we have examined these data extensively. In addition, we have analyzed some factors that relate to child supervision, including day-care attendance, family size, and structure, and employment of parents. These findings will be presented in a future report.

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